Building Children's Brains

by Joan Lessen-Firestone, Ph.D.

Many things can wait.
The child cannot.
Now is the time
His bones are being formed,
His blood is being made,
His mind is being developed.
To him, we cannot say *tomorrow.*
His name is *today.*

—Gabriella Mistral

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Introduction

For countless generations, young children have cuddled in their parents' arms, grabbed and explored interesting objects, and bounced and crawled as soon as they were able. While such behaviors usually are tolerated and often encouraged, only recently have we begun to understand their critical importance in building children's brains. Almost 80 percent of our knowledge about the brain has been developed during the past five years through such modern technologies as positron emission tomography (PET) scans.

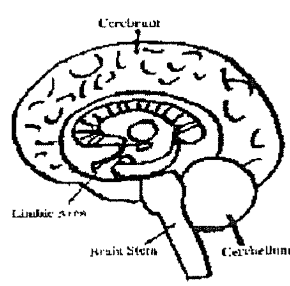
We now know that the "wiring" of a child's brain, unlike his/her skeletal system, is not determined before birth. The brain's wiring occurs in direct response to the environmental input the child receives after s/he is born. The brain of a child who has happily spent his/her first five years hearing and speaking English, playing the violin, and swimming in a lake will wire itself differently from that of child who contentedly spends those years learning Japanese and Russian, exploring the computer, and playing on swings and teeter-totters. More significant is the fact that these two children's brains will both look and perform very differently from that of a child who spent his/her first years in a stress-filled environment without much language, much stimulation, or much nurturing.

By the time children enter kindergarten, a great deal of the emotional and intellectual wiring of their brains has been set. Whether children are on a path leading to academic success and positive social behavior or to school failure and violence is determined largely by the manner in which this wiring has occurred. For the first time, we now understand how and why this happens.

Four Major Parts

Understanding four major parts of the brain will help explain how it functions (see Figure 1).

FIGURE 1
Side View of the Human Brain



BRAIN STEM

The *brain stem* is at the base of the brain and, since the brain develops from the bottom up, is the first part of the brain to become active. It serves two functions, both critical for survival. First, it controls such automatic functions as heartbeat and breathing, which, for the child to live, must operate from the moment of birth. Second, it is the area associated with "fight or flight." Whenever the child feels threatened or fearful, s/he will revert to functioning in this area of the brain and act quickly, without thought or planning, to survive.

CEREBELLUM

Above the brain stem is the *cerebellum*, which is associated with movement. This densely packed area has many connections with the parts of the brain related to abstract thinking and mental focus. When young children do not move and exercise regularly, the connections are weaker than they otherwise would be, and thinking and focus suffer. *Vestibular* stimulation, such as swinging and spinning, particularly supports one's ability to focus.

LIMBIC

The *limbic* area, or emotional center, of the brain is next. This area of the brain works differently from the other areas in that it contains structures that secrete substances into the blood stream. These substances circulate throughout the body, affecting how we feel and act. This is the area of the brain that releases adrenaline when one is stressed.

CEREBRUM

The *cerebrum* is the highest part of the brain and deals with thought processes. At the top and front of the cerebrum, almost below the natural hairline, is the *frontal cortex*. This is the area in which abstract thought occurs. It is not fully developed until children are about eight years old. The other parts of the cerebrum, which are connected to sensory input, develop earlier. This explains young children's ability to deal with concrete objects they can see, feel, taste, and smell before they can think about abstract ideas that do not have a sensory connection.

The cerebrum is covered by the *cortex* (Latin for "bark"). New research indicates that the cortex varies in thickness among individuals, and the thickness of the cortex, rather than the size or weight of the entire brain, is related to how smart individuals are—that is, how quickly they can solve problems and learn new tasks. We now know that the experiences a child has determine the thickness of his/her cortex. We also know what types of experience thicken the cortex and what types do not.

Certainly, genetic inheritance plays a role in children's intelligence. But rather than set an absolute level of intelligence, heredity seems to set the *range* within which a child's intelligence is likely to fall. The environmental experiences a child receives determine the absolute level reached within this range. It currently is thought that the range of intelligence set by heredity encompasses about 40 I.Q. points. For example, a child may be born with a possible I.Q. range of 80–120. His/her experiences in the first years of life determine where in this range s/he ultimately will fall—and if, for example, high school will be a struggle or college a success.

Neurons

The important cells in the cortex are neurons (see Figure 2). All 100 billion neurons that an individual ever will possess are present in the brain at birth. Each first resembles a spindly young tree before it develops its elaborate system of branches and roots. Each is fairly isolated and does not communicate with other neurons through its branches (*dendrites*) or roots (*axons*). As infants begin to receive appropriate stimulation—stimulation that is sensory, novel, and challenging, such as the sight and sound of a new rattle—the neurons begin to branch out. When babies begin to realize that two objects are similar ("I can suck a breast, and I can suck a bottle") or that two events are related ("When mommy comes in my room, I get picked up"), neurons begin to communicate with one another. The more communication that occurs, the more branching that occurs, and the denser the forest of neurons becomes. Even though no new neurons are created, the cortex becomes thicker because of the extensive network of branches and roots that develop among the existing neurons when children receive appropriate stimulation.

BIRTH TO THREE: NEURONS BRANCH AND CONNECT

The development of neurons, and the attendant change in brain interconnectedness, does not happen with equal ease throughout one's life. It is during the first three years of life that brain growth occurs most quickly and easily: Multitudes of new connections are made every day. This is not surprising if we consider the external changes that occur from birth to three years.

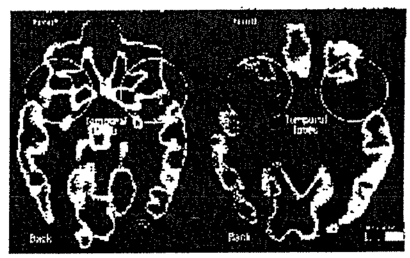
During this first three years, normally developing children learn to speak, think, and perform sophisticated movements and build interpersonal relationships. There is no other three-year period in life during which we come close to matching the rate of these accomplishments. PET scans comparing the brains of healthy and neglected three-year-olds clearly show that this growth occurs as a function of the environment rather than heredity (see Figure 3).

THREE TO NINE: CONNECTIONS CONSOLIDATE

After age three, it becomes somewhat more difficult for neural connections to be made, but until about age nine, when the hormones associated with puberty come into play, the brain still has good potential to grow and change. It is, in fact, during this time—from about three to nine—that the brain uses the most energy in its work (see Figure 4). The brain of a child in this age range daily uses twice as much glucose energy as it will at any other time in his/her life. Almost 50 percent of the calories that young children consume are used to support this intense brain activity, much of which has to do with consolidating the growth of neural pathways. In the first three

FIGURE 2
Complex Neuronal Fields

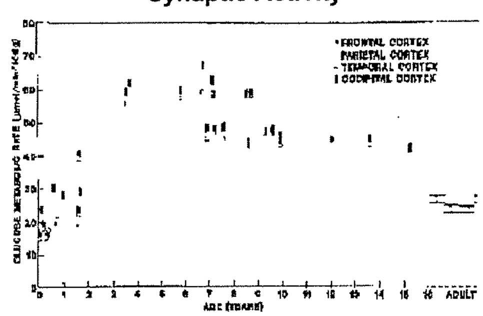
FIGURE 3
Effect of Extreme Deprivation



Healthy Child | Neglected Child

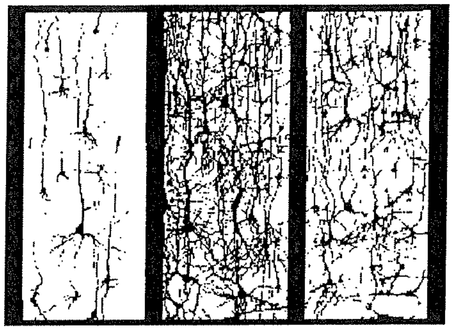
SOURCE: H.T. Chugani, Wayne State University.

FIGURE 4
Synaptic Activity



SOURCE: H.T. Chugani, Wayne State University.

FIGURE 5
Human Brain Development



Human Brain at Birth | 6 Years Old | 14 Years Old

SOURCE: H.T. Chugani, Wayne State University.

years, pathways proliferate wildly as each new experience and stimulus lead to the growth of new connections. The more connections that are made, the more possibilities that exist. Beginning about age three, the connections are pruned and refined—consolidated—with the result that only those that are well used and meaningfully connected to the child's life remain (see Figure 5).

The Early Years Are Critical

After consolidation is complete, at around age nine or ten, the brain loses much of its plasticity, and changes in wiring become much harder to make. People who learn to speak a foreign language after age ten, for example, rarely will be mistaken for a native speaker of that language. During the first year of life, children make all sounds of every language and, in so doing, develop neural connections that allow these sounds to be perfectly made. But if the sounds are not reinforced by adults and used regularly by the child, the early connections will disappear during the period of consolidation. Even extensive practice during later life never will recreate these original connections.

The critical period for developing other skills is even shorter. Infants, for instance, occasionally are born with cataracts. It appears as if their eyes, visual nerves, and visual area of the cortex would function perfectly if only the cloudy coverings over the eyes were removed. If the cataracts are removed during the child's first two years, s/he quickly gains visual abilities and soon is indistinguishable from any child born without cataracts. If the operation occurs after a child's second birthday, however, it is useless—s/he will never regain the ability to see. The critical period for developing vision has passed, and the opportunity for the child to see has been lost forever.

Stress is Devastating

The remarkable growth and development of the neural cortex during the earliest years of life can occur only when a child feels emotionally secure in warm, stable relationships. When young children are stressed, fearful, or insecure, the limbic (emotional) area of the brain actually prevents learning from occurring.

Whenever a child feels stressed or frightened, a structure in the limbic system responds by secreting *cortisol* into the bloodstream. This circulates through the body and washes over the neural cortex, where it prevents neural connections from being formed and strengthened. Even if excellent opportunities for stimulation and learning are present in the environment, children who are stressed cannot take advantage of them to develop their brains. Unable to use the higher, thinking part of the brain, children revert to functioning in the lower area of the brain stem and use the survival mechanisms of fight or flight to cope with their situation. It is only when the period of stress ends, and children again feel secure, that learning and higher-level thought processes can resume.

The relationship among fear, cortisol, and learning exists throughout life. Even adults with mature coping skills cannot learn or even think clearly when under too much stress. Infants, because they are dependent on others to fulfill their every need, are much more likely than individuals of any other age to frequently feel panic or fear.

If children live under stressful conditions for significant periods of time in their first two years, the results are disastrous. For it is during this time that the emotional center of the brain is being refined, and its entire developmental course is altered when it experiences frequent high levels of stress and the corresponding high levels of cortisol. Repeated exposure to a great deal of cortisol programs the child's brain to expect, like, and even seek situations that will lead to the release of cortisol. This happens in much the same way that children who live in a home where food is highly salted learn to prefer it that way. Children who become accustomed to high cortisol begin to live in the brain stem, rather than the thinking cortex, and view each interaction as one that threatens their survival. The teacher who is reaching out to them is not doing so to give a welcoming pat but an aggressive hit or shove. The child, without thinking, immediately responds by hitting the teacher first or running away. It is quite possible that the tremendous increase in seemingly random acts of violence in our society is related to the increased number of children responding to high levels of early stress and fear by living in their brain stems.

A Final Word

During the past several years our knowledge and understanding of brain growth and development has grown exponentially. We now know how to provide environmental stimulation that will create optimal neural wiring in the cortex and encourage the development of thoughtful, academically competent adults. We understand the critical connection between the quality of infants' emotional relationships and their later social behavior. And we realize that some windows of opportunity for affecting children's brain development are remarkably brief. Our challenge now is to act on this knowledge to ensure that every child born in Michigan reaches kindergarten with the intellectual and emotional foundation necessary to enable him/her to become a productive, contributing citizen.